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Purdue University

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AN ANALYSIS OF SOME DIFFERENCES
BETWEEN ONE AND TWO-HANDED
INDUSTRIAL WORK

Ischinger

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AN ANALYSIS OF SOME DIFFERENCES BETWEEN
ONE AND TWO-HANDED INDUSTRIAL WORK

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A Thesis

Submitted to the Faculty

of

Purdue University

by

Eric Ischinger Jr. [1921 -]

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

in

Industrial Engineering

June, 1950

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IN THE TWO-HALF-CENTURY HISTORY OF THE

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ACKNOWLEDGMENT

The author wishes to express his gratitude to the many persons who have contributed much of their time and effort in making this study possible.

Much credit is due Professors H. T. Amrine and W. J. Richardson for their valuable advice, suggestions, and encouragement. It was through them also that access was gained into the plants in which the studies were made.

The author is indebted to the Colgate-Palmolive-Peet Company, Jeffersonville, Indiana, the Duncan Electric Company, Lafayette, Indiana, and the Stephen A. Young Company, Flora, Indiana, for making available their personnel and facilities. Sincere appreciation is extended to the personnel, both in the offices and the shops, for their assistance and cooperation without which this study would not have been possible.

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The author wishes to express his appreciation to the many persons who have contributed much to their time and effort in making this study possible.

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The author is indebted to the following companies, for their cooperation, advice, and facilities: the American Electric Company, Indianapolis, and the American A. Young Company, Ellettsville, Indiana, for making available their personnel and facilities. Kinross Corporation is thanked for the personnel, both in the office and the shop, for their assistance and cooperation without which this study would not have been possible.

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ABSTRACT

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The purpose of this report is to present the results of a study of the effect of the concentration of a solution of a certain substance on the rate of a certain reaction. The study was conducted by measuring the time required for a certain amount of the substance to react with a certain amount of another substance. The results of the study are presented in the following table:

| Concentration of Solution (g/l) | Time Required for Reaction (min) |
|---------------------------------|----------------------------------|
| 0.1 | 10.0 |
| 0.2 | 5.0 |
| 0.3 | 3.3 |
| 0.4 | 2.5 |
| 0.5 | 2.0 |

From the above table it can be seen that the time required for the reaction to take place decreases as the concentration of the solution increases. This is in accordance with the law of mass action, which states that the rate of a reaction is proportional to the product of the concentrations of the reactants.

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ABSTRACT

In the system of stop watch time study advanced by Dr. M. E. Mundel¹ the rating of an operator's performance is based upon a comparison between the pace or rate of activity of the operator and a standard rate of activity. A correction is then applied for what are now termed allowances and secondary adjustments.² One of these secondary adjustments is made for bimanualness or bimanual activity. For the purpose of this discussion a bimanual operation is defined as one requiring the simultaneous symmetrical motion of both hands.

Previous studies³ conducted at the University of Iowa show a difference in cycle time between one and two handed operations of approximately 30%. The adjustment now applied for bimanual activity is 10% based on the above figure tempered by judgement and experience in application. It was the purpose of this study to substantiate the previous research in part and to determine a more nearly correct value for this adjustment.

It was intended in this experiment to minimize the

-
1. M. E. Mundel, Systematic Motion and Time Study; (New York, Prentice Hall, 1947) p. 128.
 2. M. E. Mundel, Motion and Time Study Principles and Practice; (New York, Prentice Hall, 1950) Chapter 18 (Manuscript before press.)
 3. R. M. Barnes, M. E. Mundel, and J. M. MacKenzie, "Studies of One and Two-Handed Work," (University of Iowa Studies in Engineering, Bulletin 21, 1940).

In the system of stop watch time study introduced by Dr. W. L. Lumsden, the rating of an operator's performance is based upon a comparison between the pace or rate of activity of the operator and a standard rate of activity. A correction is then applied for what are now termed allowances and secondary adjustments. One of these secondary adjustments is made for dissimilarity of movement activity. For the purpose of this discussion a dissimilarity operation is defined as one requiring the simultaneous symmetrical motion of both hands.

Previous studies conducted at the University of Iowa show a difference in cycle time between one and two handed operations of approximately 30%. The adjustment now applied for dissimilarity activity is based on the above figure tempered by judgment and experience in application. It was the purpose of this study to substantiate the previous research in part and to determine a more nearly correct value for this adjustment.

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1. W. L. Lumsden, Systematic Motion and Time Study; (New York, Prentice Hall, 1937) p. 124.

2. W. L. Lumsden, Motion and Time Study Principles and Practice; (New York, Prentice Hall, 1950) Chapter 10 (Secondary Adjustments).

3. W. L. Lumsden, W. E. Lumsden, and J. E. Lumsden, "Studies of One and Two-Handed Work," University of Iowa Studies in Engineering, Vol. 11, No. 1, 1940.

error in the previous laboratory study believed attributable to inexperience and laboratory conditions. For that reason the subjects in this study were experienced operators doing industrial jobs requiring bimanual activity. A total of eight operators on five different operations were selected. Each operator performed the operation first bimanually, then with the preferred hand alone and finally with the non-preferred hand. A short practice period was included between each phase.

Each study was recorded on 16 mm. motion picture film with time included by means of having a microchronometer placed in the field of view. This procedure made possible a very accurate determination of cycle time. A sufficient number of cycles were photographed to obtain a statistically reliable mean cycle time for each operation.

From the mean of the cycle times there was calculated a percent increase in cycle time required for bimanual activity over that required using the preferred hand. The mean percent increase in cycle time was found to be 17.852%. Since the percent increase in cycle time is symmetrically distributed about the mean, the mean is the best measure of central tendency.⁴ It is concluded then that a value of 18% is more nearly the correct adjustment to be applied for bimanualness.

4. P. G. Hoel, Introduction to Mathematical Statistics; (New York, Wiley and Sons, Inc., 1947) p. 8, 18.

error in the previous laboratory study believed attributable to inexperience and laboratory conditions. For these reasons the subjects in this study were experienced operators doing industrial jobs requiring manual activity. A total of eight operators on five different operations were selected. Each operator performed the operation three times.

When the operator had done and timing with the non-rotated hand, a single position period was indicated by a green light.

When study was recorded on 10 cm. motion picture film with time indicated by means of timing - at continuous points in the field of view. This procedure made possible a very accurate determination of cycle time. A continuous number of cycles were photographed in order to obtain a total of 10 cycles when cycle time for each position.

From the mean of the cycle times there was calculated a percent increase in cycle time required for the hand activity over that required using the rotated hand. The mean percent increase in cycle time was found to be 37.8%. Since the percent increase in cycle time is symmetrically distributed about the mean, the mean is the best measure of central tendency. It is concluded that that a value of 37.8 is more nearly the correct adjustment to be applied to the time.

AN ANALYSIS OF SOME DIFFERENCES BETWEEN ONE AND TWO-HANDED INDUSTRIAL WORK

INTRODUCTION

"Stop watch time study is used to find the amount of time necessary to accomplish a unit of work using a given method under given conditions of work, by a worker possessing a specified amount of skill on the job and a specified aptitude for the job, when working at a pace that will produce, within a unit of time, a specified physical effect upon him."¹

There are four principal steps in the mechanics of taking a stop watch time study, namely:

1. Recording the method.
2. Recording the time.
3. Rating the operator.
4. Application of allowances and secondary adjustments.

It is a very small portion of the fourth step listed which is the subject of this study.

In the system of stop watch time study² advanced by Dr. M. E. Mundel, rating, which is the third step mentioned in the preceding paragraph, is accomplished by relating

1. Mundel, Systematic, p. 128.

2. Ibid.

INTRODUCTION

Stop watch time study is used to find the amount of time necessary to accomplish a unit of work under a given method under given conditions of work, by a worker possessing a specified amount of skill on the job and a specified aptitude for the job, when working at a rate that will produce, within a unit of time, a specified quantity of product upon him.

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In the system of stop watch time study, advanced by Mr. L. B. Munz, rating, which is the third step mentioned in the preceding paragraph, is accomplished by relating

1. Munz, L. B., *Systematic*, p. 128.

2. Ibid.

the performance of an operator to a standard by a comparison of pace alone. The fallacy of such a system without secondary adjustments for job difficulty is apparent when one considers the following exaggerated case. Suppose the rate of activity of a worker handling fifty pound weights is compared to that of a man dealing cards as a standard. Due to job difficulty the pace at which the former works cannot possibly approach that rate of activity which is the standard. An adjustment is therefore made to the rating for the degree of job difficulty - in this case the weight handled. In a like manner, but to a lesser degree, an adjustment must be made for bimanual activity.

In studies³ conducted at Iowa University there was found to be an increase in cycle time of approximately 30% when performing a simple operation bimanually over that needed to perform the operation with only one hand. From experience in the application of the adjustment for bimanualness it has been determined that a value of 30% is too great and an adjustment of 10% is now being used.

An examination of the Iowa studies suggests that the error believed to be included in the results might be attributed to a lack of experience on the part of the operators. The operators were students whose performances were recorded after a minimum of training. Equal training or practice periods were allocated to each phase of

3. Barnes, Mundel, MacKenzie, Op. Cit.

the performance of an operation in a sequence of operations.
 non of these cases. The failure of some of these
 secondary adjustments for job difficulty is apparent when
 one considers the following hypothetical case. Suppose the
 rate of activity of a worker handling 1000 pounds weight
 is reported to that of a man doing work in a standard.
 Due to job difficulty the rate at which the worker works
 becomes excessively approach that rate of activity which is the
 standard. An adjustment is therefore made to the rating
 for the degree of job difficulty - in this case the rating
 remains. In a like manner, but to a lesser degree, an ad-
 justment must be made for physical activity.

In studies² conducted at Iowa University there was
 found to be an increase in cycle time of approximately 50%
 when performing a single operation continuously over time
 needed to perform the operation with only one hand. This
 experience in the application of the adjustment for job
 nonstandardness it has been determined that a value of 10% is
 too great and an adjustment of 10% is now being used.

An examination of the Iowa studies suggests that the
 error believed to be included in the results might be at-
 tributed to a lack of experience on the part of the op-
 erators. The operators were students whose performance
 were recorded after a minimum of practice. These results
 are on human data which were allocated to each phase of

the study. The operators performed the operation first with only one hand and then bimanually. Although the operation was a relatively simple one, it is possible that a marked degree of proficiency was attained using only one hand and that the same degree of proficiency was not reached in the bimanual operation.

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 a method beyond of redundancy was obtained using only one
 hand and that the same degree of proficiency was not reached
 in the bimanual operation.

It is not surprising, therefore, that the operators who
 learned to perform the operation with one hand were able to
 perform it more efficiently than those who learned to perform
 it with two hands. This is especially true when the operators
 were required to perform the operation with one hand while
 the other hand was occupied with another task. In this case,
 the operators who learned to perform the operation with one
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 hand were able to perform it more efficiently than those who
 learned to perform it with two hands.

PURPOSE

The purpose of this investigation is to determine the adjustment for bimanualness which should be applied in making a stop watch time study when using a pace-rating system.

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The purpose of this investigation is to determine the
relationship for diamondstone which should be called in work.
and a study which will show a good-looking system.

PROCEDURE

This experiment was designed primarily to eliminate lack of experience as a factor influencing the results. Operators were selected who had considerable experience or who demonstrated the equivalent in aptitude and proficiency on bimanual jobs in industry. It appears reasonable to conclude that these operators must possess equal skill in using only one hand separately to do the identical job. Any lack of familiarity or awkwardness in performing the job with one hand was minimized by allowing short practice periods for the operators.

In addition it was intended to minimize all variables except those which are uniquely attributable to bimanual activity. Jobs were selected which required a minimum of eye-hand coordination in order to minimize the effect of that variable for which a separate correction is made. The weights of parts handled by the operator were negligible and no part of the cycle was machine paced. It might appear that a wide range of job cycle times is desirable for a study of this kind. However, all but two jobs selected had comparatively short cycle times. A short cycle was characteristic of the jobs from which the selection for this study was made and is typical of a wide variety of bimanual jobs. Eight operators on five different jobs were selected.

Once the operator was selected, the purpose, procedure

This experiment was designed primarily to investigate lack of experience as a factor influencing the results. Operators were selected who had considerable experience on who demonstrated the equivalent in aptitude and proficiency on simulated jobs in industry. It appears reasonable to conclude that these operators must possess what will be used only one hand separately to do the identical job. Any lack of facility or awkwardness in performing the job with one hand was minimized by allowing about practice periods for the operators.

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Once the operator was selected, the purpose, procedure

and scope of the study were explained to him. He was instructed to perform each phase of the study using exactly the same method and at the maximum pace which he could attain. He was assured that the motion pictures would not be used by the company in setting standards or in any way which would affect the job either directly or indirectly. The operator was given an opportunity to ask any questions he wished concerning the procedure and objectives of the study. In that way it was attempted to obtain the complete confidence and cooperation of the operator before the study was begun.

The operator first performed the operation bimanually, then with the preferred hand, and finally with the non-preferred hand. A brief practice period was allocated between each phase to enable the operator to become adapted to performing the operation with only one hand. The operator's performance was recorded using a motion picture camera. A sufficient number of cycles were photographed to insure a statistically reliable average cycle time.

The motion pictures were taken on Eastman Kodak Super XX film at 16 frames per second using an Eastman Kodak Cine Special 16 mm. camera with an f 1.9 lens. Photoflood lights were used to supplement the light normally available to the worker in order to insure satisfactory exposures. A microchronometer was placed in the field of view of the camera in order to provide a measure of time on the film. The film is available for reference in the Motion and Time

and scope of the study were explained to him. He was in-
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 the same method and at the maximum pace which he could at-
 tain. It was ensured that the motion picture camera would not
 be used by the company in setting standards or in any way
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 he wished concerning the procedure and objectives of the
 study. In each way it was attempted to obtain the com-
 plete confidence and cooperation of the operator before the
 study was begun.

The operator first performed the operation manually,
 then with the prepared hand, and finally with the non-
 prepared hand. A brief practice period was allowed be-
 fore each phase to enable the operator to become adapted
 to performing the operation with only one hand. The op-
 erator's performance was recorded using a motion picture
 camera. A sufficient number of cycles were photographed
 to insure a statistically reliable average cycle time.

The motion pictures were taken on Eastman Kodak Super
 16 film at 16 frames per second using an Eastman Kodak
 Cine Special 16 mm. camera with an f.1.5 lens. Sufficient
 lights were used to supplement the light normally available
 to get proper exposure in order to insure satisfactory exposures.
 A microprojector was placed in the field of view of the
 camera in order to provide a measure of time on the film.
 The film is available for reference in the motion picture

Study Laboratory, Purdue University.

After the film was processed, it was analyzed. For this work, a small, inexpensive, hand-crank operated motion picture projector was used to view the film in a darkened room. The projector was fitted with a heat dispensing adaptor in order that a single frame could be viewed for any length of time without danger of burning the film. The analysis consisted of determining and recording the time required for each cycle. Those cycles were not included which incorporated fumbles or irregularly occurring elements not inherent in the operation. The procedure used in analyzing the film was to pick out a well defined therblig⁴ in the operation and record the time value shown on the microchronometer each time that therblig occurred. The difference between the successive time values becomes the cycle time which was computed and recorded.

4. Mundel, Systematic, p. 105.

DATA

The data for this study consists of a tabulation of the cycle times required by each operator to perform his particular operation bimanually, with the preferred hand, and with the non-preferred hand. These tables, Tables 3 through 10, and job descriptions, Figures 3 through 7, appear in the Appendix.

In each case a sufficient number of cycles were photographed to obtain a statistically reliable mean cycle time for each set of data. In order to substantiate this, one has only to apply the formula:⁵

$$N' = \left(\frac{40\sqrt{N\sum t^2 - (\sum t)^2}}{\sum t} \right)^2$$

where,

N^1 = the number of cycles required to establish the probability that 95 times out of 100 the average cycle time will be within $\pm 5\%$ of the true average representing the observed performance.

N = the number of cycles recorded.

t = the individual cycle times.

For each set of data N^1 was found to be smaller than N , and thus the reliability of the mean at the 5% level was established. The 5% confidence level is an industrially

5. M. E. Mundel, "How Many Readings in a Time Study," ("Modern Management" August, 1949).

The data for this study consists of a compilation of the cycle times recorded by each operator in various industrial operations. The data was collected from the records of the various departments of the company. The data was collected from the records of the various departments of the company. The data was collected from the records of the various departments of the company.

In each case a sufficient number of cycles were observed to obtain a statistically reliable mean cycle time for each set of data. In order to substantiate this, the data was analyzed by the following formula:

$$W = \left(\frac{40 \sqrt{N \sum d^2 - (\sum d)^2}}{\sum d} \right)^2$$

where:
 N = the number of cycles recorded in each set of data
 d = the individual cycle times
 $\sum d$ = the sum of cycle times recorded
 $\sum d^2$ = the sum of the squares of the individual cycle times
 W = the probability that 95 times out of 100 the average of the cycle times will be within 1% of the true average representing the observed performance.

For each set of data N was found to be smaller than 30, and thus the reliability of the mean of the 95 level was established. The 95 confidence level is an industrially

U. S. Bureau of Standards, "The Study of Time Study,"
 "Industrial Engineering," August, 1940.

accepted standard. For mathematical computations see
Table 11.

RESULTS

The mean cycle time required by each operator for each phase of the operation is recorded in Table 1.

Table 1
MEAN JOB CYCLE TIMES. \bar{t}

| Operation | Operator | Mean Cycle Time (winks) | | |
|-----------|----------|-------------------------|----------------|--------------------|
| | | Bi-manually | Preferred Hand | Non-preferred Hand |
| 1 | 1 | 36.000 | 30.893 | 31.710 |
| | 2 | 34.333 | 28.210 | 28.270 |
| | 3 | 40.133 | 33.051 | 33.088 |
| 2 | 1 | 34.895 | 30.463 | 31.571 |
| | 2 | 45.357 | 35.000 | 40.533 |
| 3 | 1 | 41.621 | 38.147 | 40.625 |
| 4 | 1 | 250.167 | 222.818 | 222.000 |
| 5 | 1 | 177.452 | 150.850 | 156.667 |

A wink is a 1/2000th part of a minute.

From the above results there was computed the percent increase in cycle time required when performing bimanually and when using the non-preferred hand over that required when using the preferred hand. That information is shown in Table 2.

The mean cycle time required by each operator for each phase of the operation is recorded in Table 1.

Table 1
MEAN CYCLE TIME

| Operator | Operator | Mean Cycle Time (secs) | Mean Cycle Time (secs) |
|----------|----------|------------------------|------------------------|
| 1 | 2 | 1 | 2 |
| 1 | 1 | 28.000 | 20.000 |
| 2 | 2 | 24.250 | 25.000 |
| 3 | 3 | 40.125 | 33.000 |
| 4 | 4 | 24.000 | 20.400 |
| 5 | 5 | 43.333 | 28.000 |
| 6 | 6 | 41.000 | 28.147 |
| 7 | 7 | 22.167 | 22.000 |
| 8 | 8 | 17.428 | 15.000 |

A week is a 1/2000th part of a minute.

From the above results there was computed the increase in cycle time required when performing the operation and when using the non-reversed hand over time required when using the reversed hand. This information is shown in Table 2.

Table 2

PERCENT INCREASE IN CYCLE TIME
OVER PREFERRED HAND TIMES

| Operation | Operator | Bimanually | Non-Preferred Hand |
|-----------|----------|------------|--------------------|
| 1 | 1 | 16.531 | 2.645 |
| | 2 | 21.705 | 0.213 |
| | 3 | 21.427 | 0.112 |
| 2 | 1 | 14.549 | 3.637 |
| | 2 | 29.591 | 15.808 |
| 3 | 1 | 9.107 | 6.496 |
| 4 | 1 | 12.274 | -0.368 |
| 5 | 1 | 17.635 | 3.856 |

The mean percent increase in cycle time for bimanual operation over that required using the preferred hand alone is determined from the above to be 17.852%.

Table 2

PERCENT INCREASE IN CYCLE TIME
OVER PREVIOUS YEAR

| Oper- ation | Oper- ation | Bi- ennially | Post- war |
|----------------|----------------|-----------------|--------------|
| 1 | 1 | 10.00 | 2.00 |
| 2 | 2 | 21.70 | 0.00 |
| 3 | 3 | 21.40 | 0.10 |
| 4 | 4 | 14.40 | 2.00 |
| 5 | 5 | 20.00 | 10.00 |
| 6 | 6 | 2.10 | 0.00 |
| 7 | 7 | 18.30 | -0.00 |
| 8 | 8 | 17.40 | 0.00 |

The mean percent increase in cycle time for biennial
operation over that reported using the preferred head alone
is determined from the above to be 17.55%.

DISCUSSION OF RESULTS

Since the cycle times in two of the eight jobs studied were comparatively long, it was believed desirable to see what effect, if any, the length of cycle time had upon the percent increase in cycle time. A simple correlation coefficient between the two was calculated using the formula:

$$r = \frac{N\sum xy - \sum x \sum y}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

$$= 0.34$$

This correlation coefficient is not significantly different from zero and, therefore, there is little correlation between the two items. To further substantiate this result a line of least squares was calculated for this data and was found to have a slope of +.029. The scattergram for this data is shown in Figure 1. For mathematical computations see Table 12.

A histogram showing the frequency distribution of the percent increase in cycle times in the class intervals 0-5%, 5-10%, 10-15%, 15-20%, 20-25% and 25-30% is shown in Figure 2. It is clearly evident that the observed values are quite symmetrically distributed about the mean which was found to be 17.852% and that, therefore, the mean value is the best measure of central tendency.⁶

6. Hoel, loc. cit.

Since the cycle times in two of the other tests varied more appreciably, it was believed desirable to use about eight, if not, the length of cycle times and upon the percent increase in cycle times. A simple correlation coefficient between the two was calculated using the formula:

$$r = \frac{N \sum xy - \sum x \sum y}{\sqrt{[N \sum x^2 - (\sum x)^2][N \sum y^2 - (\sum y)^2]}}$$

$$= 0.54$$

This correlation coefficient is not statistically different from zero and, therefore, there is little correlation between the two items. The further substantiated this result a line of least squares was calculated for this data and was found to have a slope of +0.07. The scattergram for this data is shown in Figure 1. For mathematical comparison see Table 12.

A histogram showing the frequency distribution of the percent increase in cycle times in the same intervals 0-5%, 5-10%, 10-15%, 15-20%, 20-25% and 25-30% is shown in Figure 2. It is clearly evident that the observed values are quite symmetrically distributed about the mean value and found to be 17.38% and 23.0%, therefore, the mean value is the best measure of central tendency.

This value of 18% is clearly significantly different from the 30% which was previously found in the Iowa studies.⁷ It is indeed probable that the major contributing factor to that difference is the inexperience of the operators in the previous experiment. That factor has been minimized in the present study. It is concluded that the 18% increase in cycle time is due almost entirely to what might be termed difficulty of coordination in bimanual activity.

7. Barnes, Mundel, and McKenzie, op. cit.

CONCLUSIONS

Since it has been shown that an average operator requires 18% longer to complete a cycle bimanually than when using only one hand, it follows that he must be operating at a pace 18% slower in the former case. Yet in each case he was performing at a rate of activity which represented his maximum effort. Therefore, the rating assigned to the operators performance should be identical in both instances. Using pace alone as a criterion, however, the operator when performing bimanually would be rated 18% lower than when using only the preferred hand. To make the ratings identical, a correction of 18% must be added to the rating assigned to the bimanual operation. Therefore, it is concluded that a secondary adjustment of 18% must be made to compensate for job difficulty in bimanual operations using a pace-rating system of time study.

... Since it has been shown that an average operator per-
forms the same number of errors as a highly skilled operator when
working with one hand, it follows that he must be operating
at a pace not slower in the former case. But in some
cases he has performed at a rate of activity which would
be considered a maximum effort. Therefore, the rating assigned
to the operator's performance should be identical in such
instances. Using pace alone as a criterion, however, the
operator when performing biminally would be rated 100
lower than when using only the preferred hand. To make
the ratings identical, a correction of 100 must be added
to the rating assigned to the biminal operation. There-
fore, it is concluded that a necessary adjustment of 100
must be made to compensate for the difficulty in biminal
operations using a two-handed system of time study.

APPENDIX

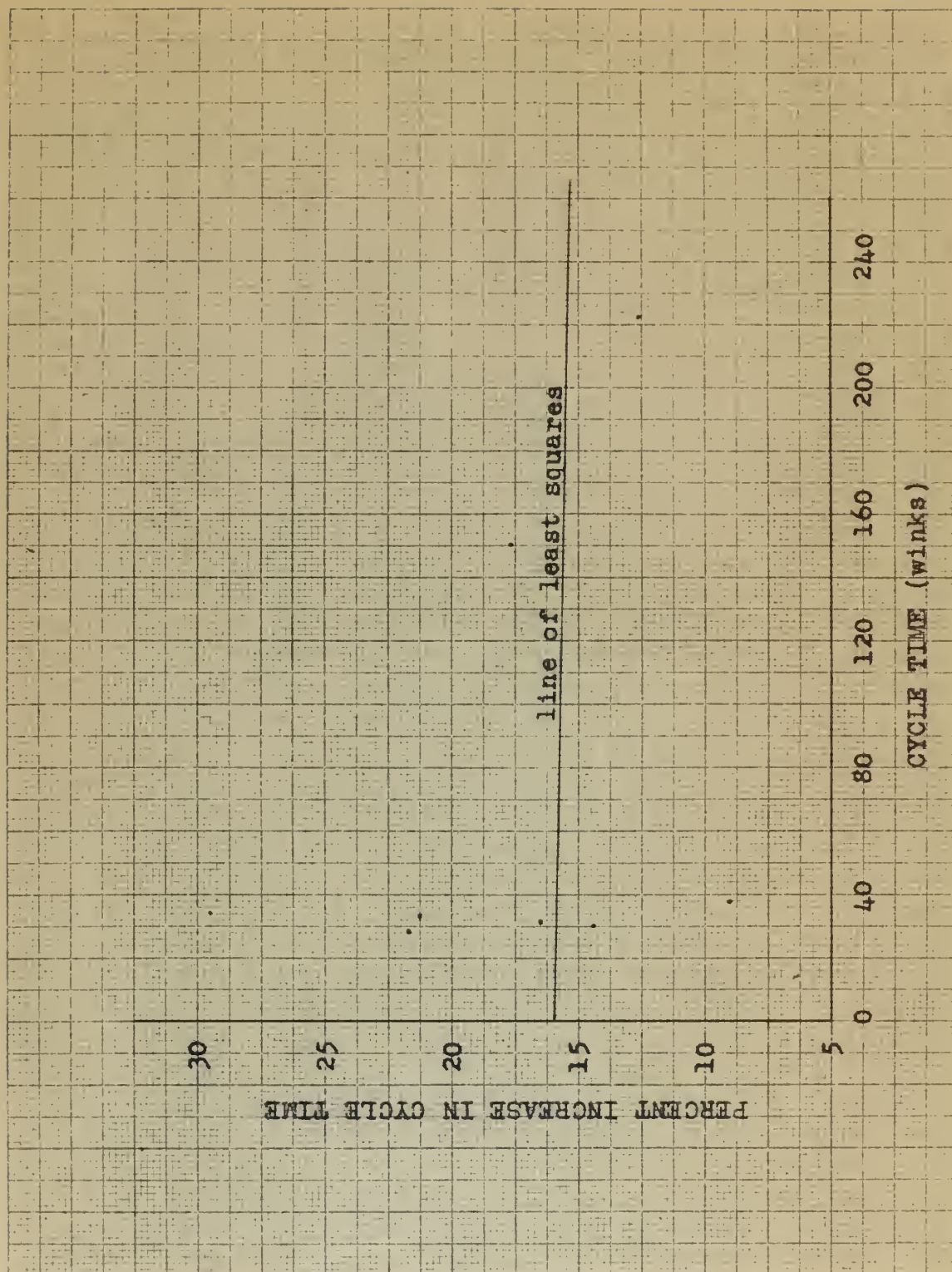


Figure 1. Mean cycle time vs. percent increase in cycle time for bimanual over preferred hand activity.

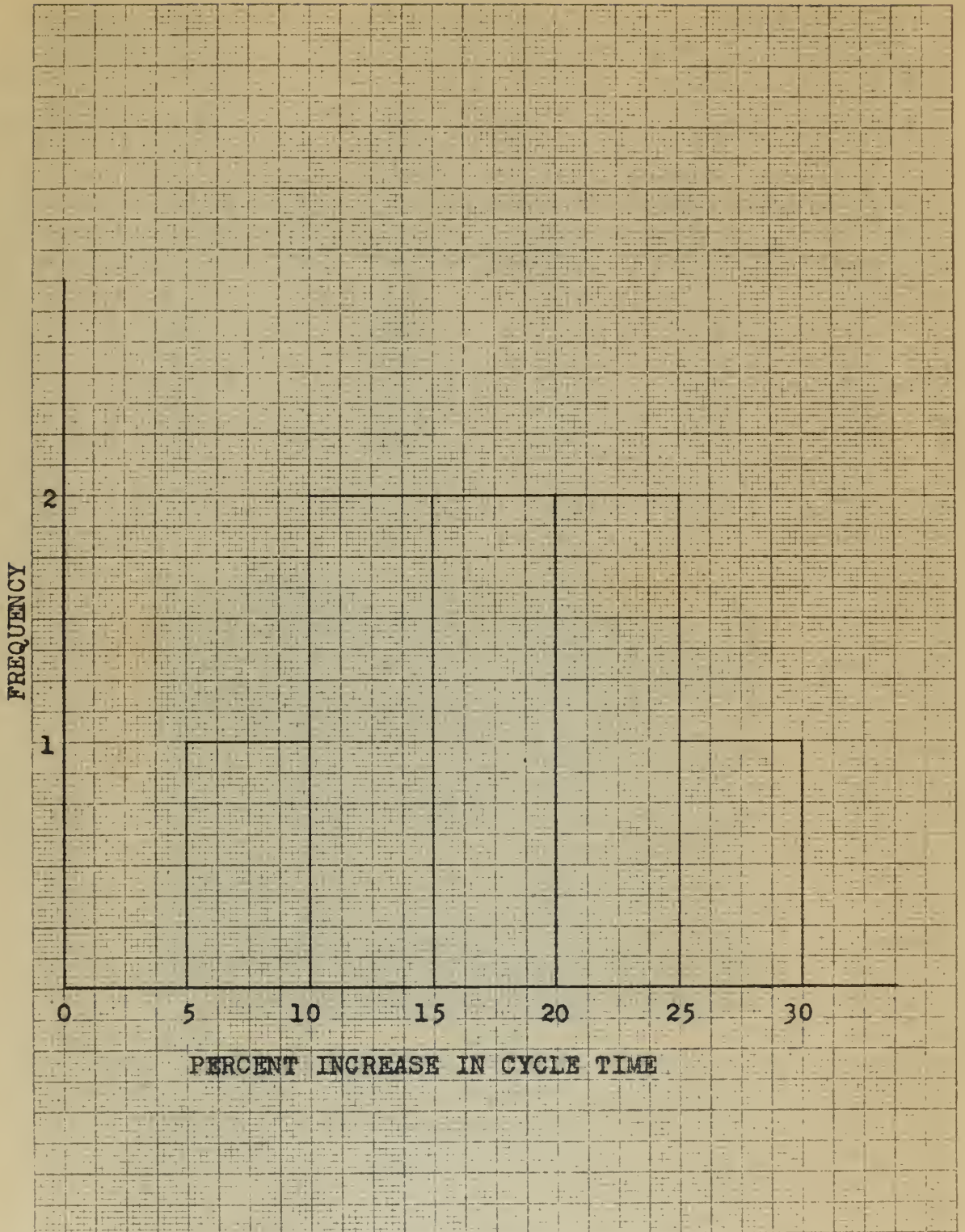


Figure 2. Histogram showing frequency distribution of percent increase in mean cycle time.

Operation: Filling carton with individual boxes of Veto.

| Description | | |
|-----------------|-------------------|-----------------|
| Left Hand | Therblig | Right Hand |
| Get box of Veto | TE, <u>Q</u> , TL | Get box of Veto |
| Place in carton | P, A, RL | Place in carton |

The therblig underlined performed by the right hand is the beginning of the cycle for the purposes of this time analysis.



Figure 3. Workplace for Packaging Veto.

operation: filling section with individual boxes of tape.

| Left Hand | Shedding | Right Hand |
|------------------|------------------|------------------|
| Get box of tape | Get box of tape | Get box of tape |
| Place in section | Place in section | Place in section |

The shedding operation performed by the right hand is the
beginning of the cycle for the purpose of this time study.
via



Figure 3. Shedding for individual boxes.

Table 3
VETO PACKAGING #1

| <u>Bimanually</u> | | <u>Preferred Hand</u> | | <u>Non-Preferred Hand</u> | |
|-------------------|----------|-----------------------|----------|---------------------------|----------|
| <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> |
| 595 | | 315 | | 784 | |
| 630 | 35 | 369* | | 814 | 30 |
| 675 | 35 | 013* | | 845 | 31 |
| 768* | | 049 | 36 | 876 | 31 |
| 806 | 38 | 573* | | 911 | 35 |
| 919* | | 566 | 29 | 132* | |
| 954 | 35 | 616* | | 165 | 33 |
| 000* | | 665* | | 200 | 35 |
| 036 | 36 | 697* | | 247* | |
| 069 | 33 | 728 | 31 | 273 | 26 |
| 230* | | 867* | | 300 | 27 |
| 267 | 37 | 897 | 30 | 330 | 30 |
| 307 | 40 | 955* | | 373* | |
| 351* | | 030* | | 411* | |
| 385 | 34 | 068* | | 543 | 32 |
| 423 | 38 | 100 | 32 | 575 | 32 |
| 572* | | 144* | | 606 | 31 |
| 612* | | 171 | 27 | 640 | 36 |
| 650 | 38 | 205 | 34 | 675 | 35 |
| 682 | 32 | 235 | 30 | 703 | 28 |
| 729* | | 265 | 30 | 734 | 31 |
| 840* | | 302 | 37 | 761 | 27 |
| 872 | 32 | 393* | | 793 | 32 |
| 912 | 40 | 434* | | 827 | 34 |
| 950 | 38 | 464 | 30 | 860 | 33 |
| 978 | 28 | 575* | | 022* | |
| 026* | | 548 | 33 | 050 | 28 |
| 315* | | 574 | 26 | 078 | 28 |
| 350 | 35 | 620* | | 116* | |
| 386 | 36 | 650 | 30 | 154* | |
| 516* | | 680 | 30 | 185 | 31 |
| 601* | | 710 | 30 | 236* | |
| 642 | 41 | 740 | 30 | 267 | 31 |
| 855* | | 771 | 31 | 300 | 33 |
| 895 | 40 | 848* | | 332 | 32 |
| 940* | | 888* | | 074* | |
| 975 | 35 | 920 | 32 | 413* | |
| 011 | 36 | 960* | | 549* | |
| | | 996 | 36 | 583 | 34 |
| | | 024 | 28 | 615 | 32 |
| | | 056 | 32 | 650 | 35 |
| | | 086 | 30 | 685 | 35 |
| | | 130* | | 720 | 35 |
| | | 160 | 30 | 752 | 32 |
| | | 193 | 33 | 780 | 28 |
| | | 226 | 33 | 812 | 32 |
| | | 323* | | 840* | |
| | | 351 | 28 | 871 | 31 |
| | | 378 | 27 | 046* | |
| | | 415* | | 078 | 32 |
| | | | | 111 | 33 |
| | | | | 150* | |
| | | | | 188* | |
| | | | | 222 | 34 |

| | | | |
|------------|--------|--------|--------|
| Σt | 792 | 865 | 1205 |
| N | 22 | 28 | 38 |
| \bar{t} | 36.000 | 30.893 | 31.710 |

T = elapsed time, t = cycle time, N = number of cycles
 \bar{t} = mean cycle time. Note: Symbols apply to Tables 3 - 10.
 *Cycle time not included because of fumble or irregularly occurring element.

Table 4
VETO PACKAGING #2

| <u>Bimanually</u> | | <u>Preferred Hand</u> | | <u>Non-Preferred Hand</u> | |
|-------------------|----------|-----------------------|----------|---------------------------|----------|
| <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> |
| 210* | | 380 | | 745 | |
| 253* | | 406 | 26 | 770 | 25 |
| 293 | 40 | 456* | | 793 | 23 |
| 327 | 34 | 509* | | 818 | 25 |
| 377* | | 535 | 26 | 847 | 29 |
| 473* | | 558 | 23 | 860* | |
| 510 | 37 | 591 | 33 | 885 | 25 |
| 549 | 39 | 621 | 30 | 055* | |
| 587 | 38 | 652 | 31 | 095* | |
| 622 | 35 | 743* | | 125 | 30 |
| 658 | 36 | 770 | 27 | 158 | 33 |
| 753* | | 797 | 27 | 183 | 25 |
| 792 | 39 | 830 | 33 | 208 | 25 |
| 830 | 38 | 865 | 35 | 245 | 37 |
| 869 | 39 | 897 | 32 | 269 | 24 |
| 911* | | 936* | | 294 | 25 |
| 948 | 37 | 964 | 28 | 376* | |
| 033* | | 985 | 21 | 405 | 29 |
| 065 | 32 | 008 | 23 | 434 | 29 |
| 099 | 34 | 037 | 29 | 463 | 29 |
| 158* | | 059* | | 493 | 30 |
| 187 | 29 | 092 | 33 | 528 | 35 |
| 218 | 31 | 192* | | 560 | 32 |
| 300* | | 220 | 28 | 586 | 26 |
| 334 | 34 | 968* | | 612 | 26 |
| 376* | | 352* | | 640 | 28 |
| 410 | 34 | 380 | 28 | 668 | 28 |
| 442 | 32 | 411 | 31 | 695 | 27 |
| 469 | 27 | 436 | 25 | 787* | |
| 550* | | 460 | 24 | 826* | |
| 580 | 30 | 490 | 30 | 856 | 30 |
| 622* | | 520 | 30 | 885 | 29 |
| 659 | 37 | 552 | 32 | 966* | |
| 693 | 34 | 638* | | 005* | |
| 728 | 35 | 664 | 26 | 034 | 29 |
| 825* | | 690 | 26 | 067 | 33 |
| 857 | 32 | 740* | | 110* | |
| 895 | 38 | 785* | | 148* | |
| 934 | 39 | 828* | | 177 | 29 |
| 962 | 28 | 867* | | 296* | |
| 990 | 28 | 946* | | 225 | 29 |
| 083* | | 974 | 28 | 254 | 29 |
| 122 | 39 | 998 | 24 | 284 | 30 |
| 157 | 35 | 085* | | 324* | |
| 193 | 36 | 111 | 26 | 452 | 28 |
| 223 | 30 | 142 | 31 | 480 | 28 |
| 250 | 27 | 172 | 30 | 507 | 27 |
| | | 202 | 30 | 532 | 25 |
| | | 234 | 32 | 557 | 25 |
| | | 264 | 30 | 587 | 30 |
| | | 291 | 27 | | |
| | | 317 | 26 | | |
| | | 361* | | | |
| | | 386 | 25 | | |
| | | 412 | 26 | | |
| <hr/> Σt | | 1072 | | 1046 | |
| N | | 38 | | 37 | |
| \bar{t} | | 28.210 | | 28.270 | |
| | 1133 | | | | |
| | 33 | | | | |
| | 34.333 | | | | |

*Cycle time not included because of fumble or irregularly occurring element.

TABLE
OF OBSERVATIONS

| 1900-1901 | | 1901-1902 | | 1902-1903 | |
|-----------|-----|-----------|-----|-----------|-----|
| 1 | 2 | 1 | 2 | 1 | 2 |
| 100 | 100 | 100 | 100 | 100 | 100 |
| 90 | 90 | 90 | 90 | 90 | 90 |
| 80 | 80 | 80 | 80 | 80 | 80 |
| 70 | 70 | 70 | 70 | 70 | 70 |
| 60 | 60 | 60 | 60 | 60 | 60 |
| 50 | 50 | 50 | 50 | 50 | 50 |
| 40 | 40 | 40 | 40 | 40 | 40 |
| 30 | 30 | 30 | 30 | 30 | 30 |
| 20 | 20 | 20 | 20 | 20 | 20 |
| 10 | 10 | 10 | 10 | 10 | 10 |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 10 | 10 | 10 | 10 | 10 |
| 20 | 20 | 20 | 20 | 20 | 20 |
| 30 | 30 | 30 | 30 | 30 | 30 |
| 40 | 40 | 40 | 40 | 40 | 40 |
| 50 | 50 | 50 | 50 | 50 | 50 |
| 60 | 60 | 60 | 60 | 60 | 60 |
| 70 | 70 | 70 | 70 | 70 | 70 |
| 80 | 80 | 80 | 80 | 80 | 80 |
| 90 | 90 | 90 | 90 | 90 | 90 |
| 100 | 100 | 100 | 100 | 100 | 100 |
| 10 | 10 | 10 | 10 | 10 | 10 |
| 20 | 20 | 20 | 20 | 20 | 20 |
| 30 | 30 | 30 | 30 | 30 | 30 |
| 40 | 40 | 40 | 40 | 40 | 40 |
| 50 | 50 | 50 | 50 | 50 | 50 |
| 60 | 60 | 60 | 60 | 60 | 60 |
| 70 | 70 | 70 | 70 | 70 | 70 |
| 80 | 80 | 80 | 80 | 80 | 80 |
| 90 | 90 | 90 | 90 | 90 | 90 |
| 100 | 100 | 100 | 100 | 100 | 100 |
| 10 | 10 | 10 | 10 | 10 | 10 |
| 20 | 20 | 20 | 20 | 20 | 20 |
| 30 | 30 | 30 | 30 | 30 | 30 |
| 40 | 40 | 40 | 40 | 40 | 40 |
| 50 | 50 | 50 | 50 | 50 | 50 |
| 60 | 60 | 60 | 60 | 60 | 60 |
| 70 | 70 | 70 | 70 | 70 | 70 |
| 80 | 80 | 80 | 80 | 80 | 80 |
| 90 | 90 | 90 | 90 | 90 | 90 |
| 100 | 100 | 100 | 100 | 100 | 100 |

Table 5
VETO PACKAGING #3

| <u>Bimanually</u> | | <u>Preferred Hand</u> | | <u>Non-Preferred Hand</u> | |
|-------------------|----------|-----------------------|----------|---------------------------|----------|
| <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> |
| 265* | | 142* | | 227* | |
| 308 | 43 | 193* | | 251 | 24 |
| 347 | 39 | 246* | | 282 | 31 |
| 403* | | 304* | | 324* | |
| 446 | 43 | 337 | 33 | 356 | 32 |
| 555* | | 376 | 39 | 566* | |
| 590 | 35 | 426* | | 598 | 32 |
| 631 | 41 | 486* | | 632 | 34 |
| 670 | 39 | 531* | | 666 | 34 |
| 707 | 37 | 562 | 31 | 699 | 33 |
| 750 | 43 | 623* | | 742* | |
| 837* | | 670* | | 770 | 28 |
| 877 | 40 | 705 | 35 | 799 | 29 |
| 938* | | 737 | 32 | 830 | 31 |
| 985 | 47 | 450* | | 863 | 33 |
| 049* | | 492 | 42 | 894 | 31 |
| 084 | 35 | 528 | 36 | 043* | |
| 201* | | 565 | 37 | 075 | 32 |
| 237 | 36 | 635* | | 108 | 33 |
| 275 | 38 | 759* | | 142 | 34 |
| 346* | | 789 | 30 | 175 | 33 |
| 384 | 38 | 813 | 24 | 215 | 40 |
| 422 | 38 | 843 | 30 | 249 | 34 |
| 547* | | 876 | 33 | 280 | 31 |
| 586 | 39 | 962* | | 314 | 34 |
| 624 | 38 | 992 | 30 | 345 | 31 |
| 664 | 40 | 025 | 33 | 376 | 31 |
| 708 | 44 | 064 | 39 | 428* | |
| 747 | 39 | 094 | 30 | 573* | |
| 863* | | 130 | 36 | 613 | 40 |
| 900 | 37 | 172 | 42 | 666* | |
| 938 | 38 | 202 | 30 | 696 | 30 |
| 977 | 39 | 237 | 35 | 736 | 40 |
| 015 | 38 | 270 | 33 | 767 | 31 |
| 054 | 39 | 300 | 30 | 804 | 37 |
| 166* | | 330 | 30 | 836 | 32 |
| 206 | 40 | 443* | | 878 | 42 |
| 255 | 49 | 470 | 27 | 921 | 43 |
| 328* | | 496 | 26 | 958 | 37 |
| 367 | 39 | 527 | 31 | 989 | 31 |
| 415 | 48 | 560 | 33 | 145* | |
| 507* | | 596 | 36 | 174 | 29 |
| 552 | 45 | 628 | 32 | 202 | 28 |
| | | 659 | 31 | 248* | |
| | | 687 | 28 | | |
| | | 715 | 28 | | |
| | | 757 | 42 | | |
| | | 782 | 25 | | |
| | | 899* | | | |
| | | 930 | 31 | | |
| | | 961 | 31 | | |
| | | 004 | 43 | | |
| | | 046 | 42 | | |
| | | 092* | | | |
| | | 125 | 33 | | |
| <hr/> | | <hr/> | | <hr/> | |
| Σt | 1204 | 1289 | | 1125 | |
| $\frac{N}{t}$ | 30 | 39 | | 34 | |
| \bar{t} | 40.133 | 33.051 | | 33.088 | |

*Cycle time not included because of fumble or irregularly occurring element.

Operation: Filling carton with individual tooth powder cans.

Description

| Left Hand | Therblig | Right Hand |
|-------------------------|-------------------|-------------------------|
| Get can of tooth powder | TE, <u>Q</u> , TL | Get can of tooth powder |
| Place in carton | P, A, RL | Place in carton |

The underlined therblig performed by the right hand is the start of the work cycle for the purpose of this time analysis.



Figure 4. Workplace for tooth powder packaging.

Operation: Fill the can with tooth powder and seal.

Preparation

| | | |
|---------------------------------------|---------------------------------------|---------------------------------------|
| Left Hand | Right Hand | Left Hand |
| Get out of tooth powder 1/2, 1/2, 1/2 | Get out of tooth powder 1/2, 1/2, 1/2 | Get out of tooth powder 1/2, 1/2, 1/2 |
| Place in can | Place in can | Place in can |

The material should be prepared by the right hand is the
start of the work for the purpose of this time only.

At.



Figure 1. Preparation for tooth powder preparation.

Table 6

TOOTH POWDER PACKAGING #1

| <u>Bimanually</u> | | <u>Preferred Hand</u> | | <u>Non-Preferred Hand</u> | |
|-------------------|----------|-----------------------|----------|---------------------------|----------|
| <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> |
| 602* | | 540* | | 368* | |
| 681* | | 567 | 27 | 405* | |
| 730* | | 619* | | 439 | 34 |
| 762 | 32 | 649 | 30 | 560* | |
| 888* | | 677 | 28 | 590 | 30 |
| 927 | 39 | 707 | 30 | 616 | 26 |
| 976* | | 735 | 28 | 647 | 31 |
| 015 | 39 | 764 | 29 | 687* | |
| 092* | | 795 | 31 | 718 | 31 |
| 123 | 31 | 822 | 27 | 761* | |
| 255* | | 945* | | 802* | |
| 287 | 32 | 976 | 31 | 832 | 30 |
| 324 | 37 | 004 | 28 | 862 | 30 |
| 360 | 36 | 035 | 31 | 891 | 29 |
| 406* | | 064 | 29 | 929* | |
| 570* | | 095 | 31 | 036* | |
| 601 | 31 | 124 | 29 | 076* | |
| 635 | 34 | 155 | 31 | 110 | 34 |
| 670 | 35 | 192* | | 140 | 30 |
| 705 | 35 | 222 | 30 | 184* | |
| 738 | 33 | 255 | 33 | 248* | |
| 879* | | 445* | | 280 | 32 |
| 918 | 39 | 535* | | 330* | |
| 952 | 34 | 570 | 35 | 372* | |
| 023* | | 670* | | 407 | 35 |
| 123* | | 702 | 32 | 444 | 37 |
| 265* | | 734 | 32 | 475 | 31 |
| 295 | 30 | 762 | 28 | 611* | |
| 330 | 35 | 793 | 31 | 645 | 34 |
| 377* | | 825 | 32 | 684* | |
| 415 | 38 | 926* | | 725* | |
| 455 | 40 | 957 | 31 | 764* | |
| 608* | | 985 | 28 | 795 | 31 |
| 645* | | 017 | 32 | 827 | 32 |
| 686* | | 055* | | 857 | 30 |
| 728* | | 085 | 30 | 887 | 30 |
| 761 | 33 | 117 | 32 | 918 | 31 |
| 805* | | 147 | 30 | 953 | 35 |
| 926* | | 183 | 36 | 984 | 31 |
| 982* | | 216 | 33 | 155* | |
| | | 246 | 30 | 183 | 28 |
| | | 288* | | 213 | 30 |
| | | 425* | | 247 | 34 |
| | | 454 | 29 | 287* | |
| | | 492* | | 318 | 31 |
| | | 522 | 30 | 351 | 33 |
| | | 554 | 32 | 385 | 34 |
| | | 585 | 31 | | |
| | | 626* | | | |
| | | 685* | | | |
| | | 720 | 35 | | |
| | | 751 | 31 | | |
| | | 781 | 30 | | |
| | | 930* | | | |
| | | 956 | 26 | | |
| | | 986 | 30 | | |
| <hr/> | | <hr/> | | <hr/> | |
| Σt | 663 | 1249 | | 884 | |
| $\frac{N}{t}$ | 19 | 41 | | 28 | |
| | 34.895 | 30.504 | | 31.571 | |

*Cycle time not included because of fumble or irregularly occurring element.

Weekly Average Temperature in

| Temperature | | Precipitation | | Wind Velocity | |
|-------------|------|---------------|-----|---------------|-----|
| 1 | 2 | 1 | 2 | 1 | 2 |
| 80.0 | 80.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 80.0 | 80.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 79.0 | 79.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 78.0 | 78.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 77.0 | 77.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 76.0 | 76.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 75.0 | 75.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 74.0 | 74.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 73.0 | 73.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 72.0 | 72.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 71.0 | 71.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 70.0 | 70.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 69.0 | 69.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 68.0 | 68.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 67.0 | 67.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 66.0 | 66.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 65.0 | 65.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 64.0 | 64.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 63.0 | 63.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 62.0 | 62.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 61.0 | 61.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 60.0 | 60.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 59.0 | 59.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 58.0 | 58.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 57.0 | 57.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 56.0 | 56.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 55.0 | 55.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 54.0 | 54.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 53.0 | 53.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 52.0 | 52.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 51.0 | 51.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 50.0 | 50.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 49.0 | 49.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 48.0 | 48.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 47.0 | 47.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 46.0 | 46.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 45.0 | 45.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 44.0 | 44.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 43.0 | 43.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 42.0 | 42.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 41.0 | 41.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 40.0 | 40.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 39.0 | 39.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 38.0 | 38.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 37.0 | 37.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 36.0 | 36.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 35.0 | 35.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 34.0 | 34.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 33.0 | 33.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 32.0 | 32.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 31.0 | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29.0 | 29.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 28.0 | 28.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27.0 | 27.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26.0 | 26.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25.0 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24.0 | 24.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 23.0 | 23.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 22.0 | 22.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 21.0 | 21.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20.0 | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19.0 | 19.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18.0 | 18.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17.0 | 17.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16.0 | 16.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15.0 | 15.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14.0 | 14.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13.0 | 13.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.0 | 10.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.0 | 9.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.0 | 8.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.0 | 7.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.0 | 6.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Table 7

TOOTH POWDER PACKAGING #2

| <u>Bimanually</u> | | <u>Preferred Hand</u> | | <u>Non-Preferred Hand</u> | |
|-------------------|----------|-----------------------|----------|---------------------------|----------|
| <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> |
| 620* | | 425* | | 355* | |
| 661 | 41 | 459 | 34 | 392 | 37 |
| 715* | | 492 | 33 | 440* | |
| 785* | | 525 | 33 | 496* | |
| 829 | 44 | 558 | 33 | 580* | |
| 917* | | 593 | 35 | 625 | 45 |
| 052* | | 640* | | 668 | 43 |
| 095 | 43 | 675 | 35 | 710 | 42 |
| 181* | | 734* | | 765* | |
| 245* | | 767 | 33 | 805 | 40 |
| 292 | 47 | 803 | 36 | 901* | |
| 345* | | 914* | | 944 | 43 |
| 480* | | 947 | 33 | 985 | 41 |
| 525 | 45 | 980 | 33 | 024 | 39 |
| 572 | 47 | 018 | 38 | 065 | 41 |
| 635* | | 054 | 36 | 123* | |
| 688* | | 107* | | 165 | 42 |
| 737 | 49 | 151* | | 206 | 41 |
| 862* | | 185 | 34 | 248 | 42 |
| 901 | 39 | 255* | | 287 | 39 |
| 949 | 48 | 295 | 40 | 326 | 39 |
| 129* | | 332 | 37 | 365 | 39 |
| 267* | | 370 | 38 | 482* | |
| 310 | 43 | 485* | | 567* | |
| 370* | | 554* | | 637* | |
| 418 | 48 | 591 | 37 | 680 | 43 |
| 474* | | 627 | 36 | 727 | 47 |
| 522 | 48 | 666 | 39 | 767 | 40 |
| 647* | | 711* | | 805 | 38 |
| 690 | 43 | 763* | | 845 | 40 |
| 740 | 50 | 855* | | 885 | 40 |
| | | 885 | 30 | 930 | 45 |
| | | 985* | | 970 | 40 |
| | | 094* | | 105 | 35 |
| | | 132 | 38 | 147 | 42 |
| | | 170 | 38 | 182 | 35 |
| | | 197 | 27 | 230* | |
| | | 232 | 35 | 283* | |
| | | 270 | 38 | 326 | 43 |
| | | 299 | 29 | 365 | 39 |
| | | 345* | | 438* | |
| | | 382 | 37 | 490* | |
| | | 419 | 37 | 532 | 42 |
| | | 452 | 33 | 574 | 42 |
| | | 485 | 33 | 640 | 36 |
| | | 584* | | | |
| | | 620 | 36 | | |
| | | 650 | 30 | | |
| | | 689 | 39 | | |
| | | 723* | | | |
| | | 760 | 37 | | |
| <hr/> | | <hr/> | | <hr/> | |
| Σt | 635 | 1190 | | 1259 | |
| N | 14 | 34 | | 31 | |
| \bar{t} | 45.357 | 35.000 | | 40.533 | |

*Cycle time not included because of fumble or irregularly occurring element.

Table

of the various groups

| Group 1 | | Group 2 | | Group 3 | |
|---------|--------|---------|--------|---------|--------|
| 1 | 2 | 1 | 2 | 1 | 2 |
| 10 | 1000 | 10 | 1000 | 10 | 1000 |
| 20 | 2000 | 20 | 2000 | 20 | 2000 |
| 30 | 3000 | 30 | 3000 | 30 | 3000 |
| 40 | 4000 | 40 | 4000 | 40 | 4000 |
| 50 | 5000 | 50 | 5000 | 50 | 5000 |
| 60 | 6000 | 60 | 6000 | 60 | 6000 |
| 70 | 7000 | 70 | 7000 | 70 | 7000 |
| 80 | 8000 | 80 | 8000 | 80 | 8000 |
| 90 | 9000 | 90 | 9000 | 90 | 9000 |
| 100 | 10000 | 100 | 10000 | 100 | 10000 |
| 110 | 11000 | 110 | 11000 | 110 | 11000 |
| 120 | 12000 | 120 | 12000 | 120 | 12000 |
| 130 | 13000 | 130 | 13000 | 130 | 13000 |
| 140 | 14000 | 140 | 14000 | 140 | 14000 |
| 150 | 15000 | 150 | 15000 | 150 | 15000 |
| 160 | 16000 | 160 | 16000 | 160 | 16000 |
| 170 | 17000 | 170 | 17000 | 170 | 17000 |
| 180 | 18000 | 180 | 18000 | 180 | 18000 |
| 190 | 19000 | 190 | 19000 | 190 | 19000 |
| 200 | 20000 | 200 | 20000 | 200 | 20000 |
| 210 | 21000 | 210 | 21000 | 210 | 21000 |
| 220 | 22000 | 220 | 22000 | 220 | 22000 |
| 230 | 23000 | 230 | 23000 | 230 | 23000 |
| 240 | 24000 | 240 | 24000 | 240 | 24000 |
| 250 | 25000 | 250 | 25000 | 250 | 25000 |
| 260 | 26000 | 260 | 26000 | 260 | 26000 |
| 270 | 27000 | 270 | 27000 | 270 | 27000 |
| 280 | 28000 | 280 | 28000 | 280 | 28000 |
| 290 | 29000 | 290 | 29000 | 290 | 29000 |
| 300 | 30000 | 300 | 30000 | 300 | 30000 |
| 310 | 31000 | 310 | 31000 | 310 | 31000 |
| 320 | 32000 | 320 | 32000 | 320 | 32000 |
| 330 | 33000 | 330 | 33000 | 330 | 33000 |
| 340 | 34000 | 340 | 34000 | 340 | 34000 |
| 350 | 35000 | 350 | 35000 | 350 | 35000 |
| 360 | 36000 | 360 | 36000 | 360 | 36000 |
| 370 | 37000 | 370 | 37000 | 370 | 37000 |
| 380 | 38000 | 380 | 38000 | 380 | 38000 |
| 390 | 39000 | 390 | 39000 | 390 | 39000 |
| 400 | 40000 | 400 | 40000 | 400 | 40000 |
| 410 | 41000 | 410 | 41000 | 410 | 41000 |
| 420 | 42000 | 420 | 42000 | 420 | 42000 |
| 430 | 43000 | 430 | 43000 | 430 | 43000 |
| 440 | 44000 | 440 | 44000 | 440 | 44000 |
| 450 | 45000 | 450 | 45000 | 450 | 45000 |
| 460 | 46000 | 460 | 46000 | 460 | 46000 |
| 470 | 47000 | 470 | 47000 | 470 | 47000 |
| 480 | 48000 | 480 | 48000 | 480 | 48000 |
| 490 | 49000 | 490 | 49000 | 490 | 49000 |
| 500 | 50000 | 500 | 50000 | 500 | 50000 |
| 510 | 51000 | 510 | 51000 | 510 | 51000 |
| 520 | 52000 | 520 | 52000 | 520 | 52000 |
| 530 | 53000 | 530 | 53000 | 530 | 53000 |
| 540 | 54000 | 540 | 54000 | 540 | 54000 |
| 550 | 55000 | 550 | 55000 | 550 | 55000 |
| 560 | 56000 | 560 | 56000 | 560 | 56000 |
| 570 | 57000 | 570 | 57000 | 570 | 57000 |
| 580 | 58000 | 580 | 58000 | 580 | 58000 |
| 590 | 59000 | 590 | 59000 | 590 | 59000 |
| 600 | 60000 | 600 | 60000 | 600 | 60000 |
| 610 | 61000 | 610 | 61000 | 610 | 61000 |
| 620 | 62000 | 620 | 62000 | 620 | 62000 |
| 630 | 63000 | 630 | 63000 | 630 | 63000 |
| 640 | 64000 | 640 | 64000 | 640 | 64000 |
| 650 | 65000 | 650 | 65000 | 650 | 65000 |
| 660 | 66000 | 660 | 66000 | 660 | 66000 |
| 670 | 67000 | 670 | 67000 | 670 | 67000 |
| 680 | 68000 | 680 | 68000 | 680 | 68000 |
| 690 | 69000 | 690 | 69000 | 690 | 69000 |
| 700 | 70000 | 700 | 70000 | 700 | 70000 |
| 710 | 71000 | 710 | 71000 | 710 | 71000 |
| 720 | 72000 | 720 | 72000 | 720 | 72000 |
| 730 | 73000 | 730 | 73000 | 730 | 73000 |
| 740 | 74000 | 740 | 74000 | 740 | 74000 |
| 750 | 75000 | 750 | 75000 | 750 | 75000 |
| 760 | 76000 | 760 | 76000 | 760 | 76000 |
| 770 | 77000 | 770 | 77000 | 770 | 77000 |
| 780 | 78000 | 780 | 78000 | 780 | 78000 |
| 790 | 79000 | 790 | 79000 | 790 | 79000 |
| 800 | 80000 | 800 | 80000 | 800 | 80000 |
| 810 | 81000 | 810 | 81000 | 810 | 81000 |
| 820 | 82000 | 820 | 82000 | 820 | 82000 |
| 830 | 83000 | 830 | 83000 | 830 | 83000 |
| 840 | 84000 | 840 | 84000 | 840 | 84000 |
| 850 | 85000 | 850 | 85000 | 850 | 85000 |
| 860 | 86000 | 860 | 86000 | 860 | 86000 |
| 870 | 87000 | 870 | 87000 | 870 | 87000 |
| 880 | 88000 | 880 | 88000 | 880 | 88000 |
| 890 | 89000 | 890 | 89000 | 890 | 89000 |
| 900 | 90000 | 900 | 90000 | 900 | 90000 |
| 910 | 91000 | 910 | 91000 | 910 | 91000 |
| 920 | 92000 | 920 | 92000 | 920 | 92000 |
| 930 | 93000 | 930 | 93000 | 930 | 93000 |
| 940 | 94000 | 940 | 94000 | 940 | 94000 |
| 950 | 95000 | 950 | 95000 | 950 | 95000 |
| 960 | 96000 | 960 | 96000 | 960 | 96000 |
| 970 | 97000 | 970 | 97000 | 970 | 97000 |
| 980 | 98000 | 980 | 98000 | 980 | 98000 |
| 990 | 99000 | 990 | 99000 | 990 | 99000 |
| 1000 | 100000 | 1000 | 100000 | 1000 | 100000 |

Operation: Filling carton with bottles of Halo.

| Description | | |
|--------------------|-------------------|--------------------|
| Left Hand | Therblig | Right Hand |
| Get bottle of Halo | TE, <u>G</u> , TL | Get bottle of Halo |
| Place in carton | P, A, RL | Place in carton |

The therblig underlined performed by the right hand represents the start of a cycle for the purpose of this time analysis.



Figure 5. Workplace for Packaging Halo.

Operation: filling carton with bottles of milk.

Operation:

| | |
|--------------------|--------------------|
| Left hand | Right hand |
| Get bottle of milk | Get bottle of milk |
| Place in carton | Place in carton |

The charting suggested performed by the right hand represents the start of a cycle for the purpose of this time analysis.



Figure 2. Sequence for filling milk.

Table 8

HALO PACKAGING

| <u>Bimanually</u> | | <u>Preferred Hand</u> | | <u>Non-Preferred Hand</u> | |
|-------------------|----------|-----------------------|----------|---------------------------|----------|
| <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> |
| 499* | | 872* | | 890* | |
| 544 | 45 | 911 | 39 | 931 | 41 |
| 673* | | 960* | | 973 | 42 |
| 712 | 39 | 040* | | 040* | |
| 756 | 44 | 085 | 45 | 090* | |
| 795 | 39 | 124 | 39 | 132 | 42 |
| 835 | 40 | 257* | | 170 | 38 |
| 878 | 43 | 300 | 43 | 220* | |
| 136* | | 337 | 37 | 282* | |
| 185 | 49 | 372 | 35 | 333* | |
| 218 | 33 | 423* | | 388* | |
| 258 | 40 | 459 | 36 | 523* | |
| 302 | 44 | 498 | 39 | 563 | 40 |
| 422* | | 540 | 42 | 610 | 47 |
| 460 | 38 | 578 | 38 | 652 | 42 |
| 502 | 42 | 624 | 46 | 717* | |
| 542 | 40 | 664 | 40 | 757 | 40 |
| 582 | 40 | 699 | 35 | 808* | |
| 628 | 46 | 828* | | 847 | 39 |
| 754* | | 878* | | 905* | |
| 796 | 42 | 916 | 38 | 960* | |
| 842 | 46 | 955 | 39 | 010* | |
| 880 | 38 | 008* | | 065* | |
| 920 | 40 | 046 | 38 | 227* | |
| 979* | | 085 | 39 | 265 | 38 |
| 107* | | 122 | 37 | 307 | 42 |
| 148 | 41 | 235* | | 347 | 40 |
| 189 | 41 | 274 | 39 | 459* | |
| 226 | 37 | 312 | 38 | 495 | 36 |
| 264 | 38 | 438* | | 540 | 45 |
| 310 | 46 | 474 | 36 | 575 | 35 |
| 417* | | 513 | 39 | 618 | 43 |
| 454 | 37 | 549 | 36 | | |
| 528* | | 599* | | | |
| 564 | 36 | 636 | 37 | | |
| 603 | 39 | 673 | 37 | | |
| 656* | | 711 | 38 | | |
| 796* | | 748 | 37 | | |
| 836 | 40 | 790 | 42 | | |
| 877 | 41 | 827 | 37 | | |
| 917 | 40 | 863 | 37 | | |
| 960 | 43 | 003 | 40 | | |
| 007 | 47 | 037 | 34 | | |
| 131* | | 068 | 31 | | |
| 172 | 41 | 102 | 34 | | |
| 216 | 44 | | | | |
| 263 | 47 | | | | |
| 310 | 47 | | | | |
| 357 | 47 | | | | |

| | | | |
|--------------------|--------|--------|--------|
| Σt | 1540 | 1297 | 650 |
| $\frac{\Sigma}{N}$ | 37 | 34 | 16 |
| $\frac{\Sigma}{t}$ | 41.621 | 38.147 | 40.625 |

*Cycle time not included because of fumble or irregularly occurring element.

Table 2

| 1947-1948 | | 1948-1949 | | 1949-1950 | |
|-----------|-----|-----------|-----|-----------|-----|
| 1 | 2 | 1 | 2 | 1 | 2 |
| 100 | 100 | 100 | 100 | 100 | 100 |
| 95 | 95 | 95 | 95 | 95 | 95 |
| 90 | 90 | 90 | 90 | 90 | 90 |
| 85 | 85 | 85 | 85 | 85 | 85 |
| 80 | 80 | 80 | 80 | 80 | 80 |
| 75 | 75 | 75 | 75 | 75 | 75 |
| 70 | 70 | 70 | 70 | 70 | 70 |
| 65 | 65 | 65 | 65 | 65 | 65 |
| 60 | 60 | 60 | 60 | 60 | 60 |
| 55 | 55 | 55 | 55 | 55 | 55 |
| 50 | 50 | 50 | 50 | 50 | 50 |
| 45 | 45 | 45 | 45 | 45 | 45 |
| 40 | 40 | 40 | 40 | 40 | 40 |
| 35 | 35 | 35 | 35 | 35 | 35 |
| 30 | 30 | 30 | 30 | 30 | 30 |
| 25 | 25 | 25 | 25 | 25 | 25 |
| 20 | 20 | 20 | 20 | 20 | 20 |
| 15 | 15 | 15 | 15 | 15 | 15 |
| 10 | 10 | 10 | 10 | 10 | 10 |
| 5 | 5 | 5 | 5 | 5 | 5 |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | 100 | 100 | 100 | 100 | 100 |
| 95 | 95 | 95 | 95 | 95 | 95 |
| 90 | 90 | 90 | 90 | 90 | 90 |
| 85 | 85 | 85 | 85 | 85 | 85 |
| 80 | 80 | 80 | 80 | 80 | 80 |
| 75 | 75 | 75 | 75 | 75 | 75 |
| 70 | 70 | 70 | 70 | 70 | 70 |
| 65 | 65 | 65 | 65 | 65 | 65 |
| 60 | 60 | 60 | 60 | 60 | 60 |
| 55 | 55 | 55 | 55 | 55 | 55 |
| 50 | 50 | 50 | 50 | 50 | 50 |
| 45 | 45 | 45 | 45 | 45 | 45 |
| 40 | 40 | 40 | 40 | 40 | 40 |
| 35 | 35 | 35 | 35 | 35 | 35 |
| 30 | 30 | 30 | 30 | 30 | 30 |
| 25 | 25 | 25 | 25 | 25 | 25 |
| 20 | 20 | 20 | 20 | 20 | 20 |
| 15 | 15 | 15 | 15 | 15 | 15 |
| 10 | 10 | 10 | 10 | 10 | 10 |
| 5 | 5 | 5 | 5 | 5 | 5 |
| 0 | 0 | 0 | 0 | 0 | 0 |

Operation: Assembling faucet sub-assembly.

| Description | | |
|-------------------------------------|------------------|-------------------------------------|
| Left Hand | Therblig | Right Hand |
| Get saw | TE, G, P | Get saw |
| Assemble with fixture | A, RL | Assemble with fixture |
| Get washer | TE, G, TL | Get washer |
| Assemble with screw | P, A, RL | Assemble with screw |
| Get swivel | TE, G, P | Get swivel |
| Assemble with screw | A, RL | Assemble with screw |
| Disassemble from fixture | TE, G, TL | Disassemble from fixture |
| Assemble with tighten- ing board | P, <u>A</u> , RL | Assemble with tighten- ing board |

The underlined Therblig represents the performed act by the right hand beginning a cycle for the purposes of this time analysis.



Figure 6. Workplace for assembling faucet sub-assemblies.

Operation: Assembly of the engine.

Procedure

| Step | Operation | Time |
|------|---------------|------|
| 1 | Get new | 1.0 |
| 2 | Assembly with | 1.0 |
| 3 | Get washer | 1.0 |
| 4 | Assembly with | 1.0 |
| 5 | Get valve | 1.0 |
| 6 | Assembly with | 1.0 |
| 7 | Assembly from | 1.0 |
| 8 | Assembly with | 1.0 |
| 9 | Get board | 1.0 |

The underlined words represent the performed work by the right hand beginning a cycle for the purpose of this time analysis.



Figure 8. Workplace for assembling the engine.

Table 9

FAUCET SUB-ASSEMBLY

| <u>Bimanually</u> | | <u>Preferred Hand</u> | | <u>Non-Preferred Hand</u> | |
|-------------------|----------|-----------------------|----------|---------------------------|----------|
| <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> |
| 238* | | 118* | | 988* | |
| 501 | 263 | 372 | 254 | 212 | 224 |
| 725 | 224 | 590 | 218 | 436 | 224 |
| 980 | 255 | 808 | 218 | 662 | 226 |
| 259 | 271 | 043 | 235 | 876 | 214 |
| 495 | 236 | 308* | | 160* | |
| 759 | 264 | 511 | 203 | | |
| 024 | 265 | 725 | 214 | | |
| 426* | | 922 | 197 | | |
| 696 | 270 | 317* | | | |
| 985* | | 530 | 213 | | |
| 410* | | 796* | | | |
| 700* | | 035 | 239 | | |
| 926 | 226 | 284 | 249 | | |
| 140 | 214 | 456* | | | |
| 391 | 251 | 741* | | | |
| 689* | | 770* | | | |
| 065* | | 981 | 211 | | |
| 328 | 263 | | | | |
| 626* | | | | | |
| <hr/> | | | | | |
| Σt | 3002 | 2451 | | 888 | |
| N | 12 | 11 | | 4 | |
| \bar{t} | 250.167 | 222.154 | | 222.000 | |

*Cycle time not included because of fumble or irregularly occurring element.

TABLE 1. - SUMMARY OF DATA

| STATION | DATE | WATER LEVEL (feet) | | WIND VELOCITY (miles per hour) | | WIND DIRECTION (degrees) | |
|---------|-------|--------------------|------|--------------------------------|----|--------------------------|----|
| | | 1 | 2 | 1 | 2 | 1 | 2 |
| 100 | 10/1 | 10.0 | 10.0 | 10 | 10 | 10 | 10 |
| 101 | 10/2 | 10.1 | 10.1 | 11 | 11 | 11 | 11 |
| 102 | 10/3 | 10.2 | 10.2 | 12 | 12 | 12 | 12 |
| 103 | 10/4 | 10.3 | 10.3 | 13 | 13 | 13 | 13 |
| 104 | 10/5 | 10.4 | 10.4 | 14 | 14 | 14 | 14 |
| 105 | 10/6 | 10.5 | 10.5 | 15 | 15 | 15 | 15 |
| 106 | 10/7 | 10.6 | 10.6 | 16 | 16 | 16 | 16 |
| 107 | 10/8 | 10.7 | 10.7 | 17 | 17 | 17 | 17 |
| 108 | 10/9 | 10.8 | 10.8 | 18 | 18 | 18 | 18 |
| 109 | 10/10 | 10.9 | 10.9 | 19 | 19 | 19 | 19 |
| 110 | 10/11 | 11.0 | 11.0 | 20 | 20 | 20 | 20 |
| 111 | 10/12 | 11.1 | 11.1 | 21 | 21 | 21 | 21 |
| 112 | 10/13 | 11.2 | 11.2 | 22 | 22 | 22 | 22 |
| 113 | 10/14 | 11.3 | 11.3 | 23 | 23 | 23 | 23 |
| 114 | 10/15 | 11.4 | 11.4 | 24 | 24 | 24 | 24 |
| 115 | 10/16 | 11.5 | 11.5 | 25 | 25 | 25 | 25 |
| 116 | 10/17 | 11.6 | 11.6 | 26 | 26 | 26 | 26 |
| 117 | 10/18 | 11.7 | 11.7 | 27 | 27 | 27 | 27 |
| 118 | 10/19 | 11.8 | 11.8 | 28 | 28 | 28 | 28 |
| 119 | 10/20 | 11.9 | 11.9 | 29 | 29 | 29 | 29 |
| 120 | 10/21 | 12.0 | 12.0 | 30 | 30 | 30 | 30 |

NOTE: The data in this table are for the period from 10/1 to 10/21, 1961. The data are for the period from 10/1 to 10/21, 1961.

Operation: Assembling watt-hour meter sub-assembly.

Description

| Left Hand | Therblig | Right Hand |
|------------------------------------|----------------------------|--|
| Get sleeve | TE, G, TL | Get sleeve |
| Assemble with fixture | P, A, RL | Assemble with fixture |
| Get washer | TE, G, TL | Get washer |
| Assemble with fixture | P, A, RL | Assemble with fixture |
| Get screw | TE, G, TL | Get screw |
| Assemble with sleeve and washer | P, A, RL <u>DA</u> , RL | Assemble with sleeve and washer Trip fixture release |

The therblig underlined performed by the right hand represents the beginning of a cycle for the purpose of this time analysis.



Figure 7. Workplace for assembling watt-hour meter sub-assembly.

Inspection

| Left Hand | Throttle | Right Hand |
|-----------------------|-----------|-----------------------|
| Get screw | 7.5, 0.75 | Get screw |
| Assembly with fixture | 7.5, 0.75 | Assembly with fixture |
| Get washer | 7.5, 0.75 | Get washer |
| Assembly with fixture | 7.5, 0.75 | Assembly with fixture |
| Get screw | 7.5, 0.75 | Get screw |
| Assembly with fixture | 7.5, 0.75 | Assembly with fixture |
| Get washer | 7.5, 0.75 | Get washer |
| Assembly with fixture | 7.5, 0.75 | Assembly with fixture |

The throttle adjustment performed by the right hand worker sends the beginning of a cycle for the purpose of this time analysis.



Figure 5. Workpiece for assembling well-head water sub-assembly.

Table 10

ASSEMBLING SLEEVE AND WASHER TO BOLT

| <u>Bimanually</u> | | <u>Preferred Hand</u> | | <u>Non-Preferred Hand</u> | |
|-------------------|----------|-----------------------|----------|---------------------------|----------|
| <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> | <u>T</u> | <u>t</u> |
| 750* | | 037* | | 707* | |
| 918 | 168 | 235 | 198 | 874 | 167 |
| 135 | 217 | 427 | 192 | 054 | 180 |
| 352* | | 553 | 126 | 179 | 125 |
| 598* | | 740 | 187 | 316 | 137 |
| 788 | 190 | 867 | 127 | 483 | 167 |
| 009 | 221 | 135 | 168 | 645 | 162 |
| 152 | 143 | 255* | | 810 | 165 |
| 556* | | 430 | 175 | 958 | 148 |
| 775 | 219 | 586 | 156 | 093 | 135 |
| 915 | 140 | 740 | 154 | 231 | 138 |
| 084 | 169 | 874 | 136 | 380 | 149 |
| 239 | 155 | 059 | 185 | 526 | 146 |
| 385 | 146 | 237 | 178 | 654 | 128 |
| 580 | 195 | 704* | | 785 | 131 |
| 791 | 211 | 874 | 170 | 930 | 145 |
| 960 | 169 | 015 | 141 | 111 | 181 |
| 103 | 143 | 152 | 137 | 647* | |
| 338* | | 304 | 152 | 867* | |
| 496 | 158 | 456 | 152 | 996 | 129 |
| 656 | 160 | 617 | 161 | 177 | 181 |
| 841 | 185 | 742 | 125 | 326 | 149 |
| 011 | 170 | 876 | 134 | 480 | 154 |
| 211 | 200 | 012 | 136 | | |
| 770* | | | | | |
| 946 | 176 | | | | |
| 089 | 143 | | | | |
| 234 | 145 | | | | |
| 431 | 197 | | | | |
| 601 | 171 | | | | |
| 805 | 204 | | | | |
| 009 | 204 | | | | |
| 237* | | | | | |
| 404 | 167 | | | | |
| 594 | 190 | | | | |
| 775 | 181 | | | | |
| 962 | 187 | | | | |
| 139 | 177 | | | | |
| <hr/> | | | | | |
| Σt | 5501 | 3290 | | 3017 | |
| $\frac{N}{t}$ | 31 | 21 | | 20 | |
| \bar{t} | 177.452 | 156.667 | | 150.850 | |

*Cycle time not included because of fumble or irregularly occurring element.

| | | | |
|--------|----------|---------|----|
| YAC | CMC | DMC | 23 |
| OP | JP | IP | 5 |
| OP, OP | YOS, JPI | DM, YPI | 7 |

Other items not included because of limited availability:
 1. 1940-1941

Table 11
CALCULATION OF N^1

| Operation | Operator | | Σt | Σt^2 | $N \Sigma t^2$ | | |
|-----------|----------|----------------|----------------|-------------------------------|----------------|-------|--|
| 1 | 1 | Preferred Hand | 865 | 26921 | 753788 | | |
| | | Non-preferred | 1205 | 38459 | 1461442 | | |
| | | Bimanually | 792 | 28716 | 631752 | | |
| | 2 | Preferred Hand | 1082 | 30644 | 1164472 | | |
| | | Non-preferred | 1046 | 29916 | 1106892 | | |
| | | Bimanually | 1133 | 39391 | 1299903 | | |
| | 3 | Preferred Hand | 1289 | 43515 | 1697085 | | |
| | | Non-preferred | 1125 | 37791 | 1284894 | | |
| | | Bimanually | 1204 | 48692 | 1460760 | | |
| 2 | 1 | Preferred Hand | 1249 | 38235 | 1567635 | | |
| | | Non-preferred | 884 | 28064 | 785792 | | |
| | | Bimanually | 663 | 23307 | 442833 | | |
| | 2 | Preferred Hand | 1190 | 41960 | 1426640 | | |
| | | Non-preferred | 1216 | 49486 | 1484580 | | |
| | | Bimanually | 635 | 28941 | 405174 | | |
| 3 | 1 | Preferred Hand | 1297 | 49779 | 1692486 | | |
| | | Non-preferred | 650 | 26550 | 424800 | | |
| | | Bimanually | 1540 | 64586 | 2389682 | | |
| 4 | 1 | Preferred Hand | 2888 | 549615 | 60457650 | | |
| | | Non-preferred | 888 | | | | |
| | | Bimanually | 3002 | 755370 | 9064440 | | |
| 5 | 1 | Preferred Hand | 3017 | 461381 | 9227620 | | |
| | | Non-preferred | 3290 | 526104 | 11048184 | | |
| | | Bimanually | 5501 | 994191 | 30819921 | | |
| | | | $(\Sigma t)^2$ | $N \Sigma t^2 - (\Sigma t)^2$ | N | N^1 | |
| 1 | 1 | Preferred Hand | 748225 | 5563 | 28 | 11.9 | |
| | | Non-preferred | 1452025 | 9417 | 38 | 10.4 | |
| | | Bimanually | 627264 | 4488 | 22 | 11.4 | |
| | 2 | Preferred Hand | 1149184 | 15288 | 38 | 20.9 | |
| | | Non-preferred | 1094116 | 12776 | 37 | 18.7 | |
| | | Bimanually | 1283689 | 16214 | 33 | 20.25 | |
| | 3 | Preferred Hand | 1661521 | 35564 | 39 | 34.3 | |
| | | Non-preferred | 1265625 | 19269 | 34 | 24.3 | |
| | | Bimanually | 1449616 | 11144 | 30 | 12.3 | |
| 2 | 1 | Preferred Hand | 1560001 | 7634 | 41 | 7.9 | |
| | | Non-preferred | 781456 | 4336 | 28 | 10.0 | |
| | | Bimanually | 439569 | 3264 | 19 | 11.9 | |
| | 2 | Preferred hand | 1416100 | 10540 | 34 | 11.9 | |
| | | Non-preferred | 1478656 | 5924 | 30 | 6.4 | |
| | | Bimanually | 403225 | 1949 | 14 | 7.4 | |
| 3 | 1 | Preferred Hand | 1682209 | 10277 | 34 | 10.1 | |
| | | Non-preferred | 422500 | 2300 | 16 | 8.7 | |
| | | Bimanually | 2371600 | 18082 | 37 | 12.2 | |

| Year | Age | Sex | Weight (kg) | Length (cm) | Condition |
|------|-----|-----|-------------|-------------|-----------|
| 1970 | 10 | M | 10.5 | 110 | Good |
| 1971 | 11 | F | 11.2 | 115 | Good |
| 1972 | 12 | M | 12.8 | 120 | Good |
| 1973 | 13 | F | 13.5 | 125 | Good |
| 1974 | 14 | M | 14.2 | 130 | Good |
| 1975 | 15 | F | 15.0 | 135 | Good |
| 1976 | 16 | M | 16.5 | 140 | Good |
| 1977 | 17 | F | 17.2 | 145 | Good |
| 1978 | 18 | M | 18.0 | 150 | Good |
| 1979 | 19 | F | 19.5 | 155 | Good |
| 1980 | 20 | M | 20.2 | 160 | Good |
| 1981 | 21 | F | 21.0 | 165 | Good |
| 1982 | 22 | M | 22.5 | 170 | Good |
| 1983 | 23 | F | 23.2 | 175 | Good |
| 1984 | 24 | M | 24.0 | 180 | Good |
| 1985 | 25 | F | 25.5 | 185 | Good |
| 1986 | 26 | M | 26.2 | 190 | Good |
| 1987 | 27 | F | 27.0 | 195 | Good |
| 1988 | 28 | M | 28.5 | 200 | Good |
| 1989 | 29 | F | 29.2 | 205 | Good |
| 1990 | 30 | M | 30.0 | 210 | Good |

| λ | μ | $\frac{1}{2}(\lambda + \mu)$ | $\frac{1}{2}(\lambda - \mu)$ | $\frac{1}{2}(\lambda + \mu)$ | $\frac{1}{2}(\lambda - \mu)$ |
|-----------|-------|------------------------------|------------------------------|------------------------------|------------------------------|
| 0.11 | 0.01 | 0.06 | 0.05 | 0.06 | 0.05 |
| 0.12 | 0.02 | 0.07 | 0.05 | 0.07 | 0.05 |
| 0.13 | 0.03 | 0.08 | 0.05 | 0.08 | 0.05 |
| 0.14 | 0.04 | 0.09 | 0.05 | 0.09 | 0.05 |
| 0.15 | 0.05 | 0.10 | 0.05 | 0.10 | 0.05 |
| 0.16 | 0.06 | 0.11 | 0.05 | 0.11 | 0.05 |
| 0.17 | 0.07 | 0.12 | 0.05 | 0.12 | 0.05 |
| 0.18 | 0.08 | 0.13 | 0.05 | 0.13 | 0.05 |
| 0.19 | 0.09 | 0.14 | 0.05 | 0.14 | 0.05 |
| 0.20 | 0.10 | 0.15 | 0.05 | 0.15 | 0.05 |

Table 11 (Continued)

| Operation | Operator | | $(\sum t)^2$ | $\frac{N \sum t^2}{(\sum t)^2}$ | N | N^1 |
|-----------|----------|----------------|--------------|---------------------------------|----|-------|
| 4 | 1 | Preferred Hand | 6007401 | 38364 | 11 | 10.1 |
| | | Non-preferred | | | 4 | |
| | | Bimanually | 9012004 | 52436 | 12 | 9.3 |
| 5 | 1 | Preferred Hand | 9102289 | 125331 | 20 | 22 |
| | | Non-preferred | 1082410 | 224084 | 21 | 33 |
| | | Bimanually | 30261001 | 558920 | 31 | 29.4 |

Table 11 (continued)

| Year | Age | Sex | Weight (kg) | Length (cm) | Condition | Notes |
|------|-----|-----|-------------|-------------|-----------|-------|
| 1971 | 11 | M | 55.5 | 107.0 | Good | |
| 1971 | 11 | F | 55.5 | 107.0 | Good | |
| 1971 | 11 | M | 55.5 | 107.0 | Good | |
| 1971 | 11 | F | 55.5 | 107.0 | Good | |
| 1971 | 11 | M | 55.5 | 107.0 | Good | |
| 1971 | 11 | F | 55.5 | 107.0 | Good | |
| 1971 | 11 | M | 55.5 | 107.0 | Good | |
| 1971 | 11 | F | 55.5 | 107.0 | Good | |
| 1971 | 11 | M | 55.5 | 107.0 | Good | |
| 1971 | 11 | F | 55.5 | 107.0 | Good | |

Table 12

COMPUTATION OF CORRELATION COEFFICIENT
 BETWEEN MEAN CYCLE TIMES FOR PREFERRED HAND OPERATION
 AND PERCENT INCREASE IN CYCLE TIME FOR BIMANUAL OPERATION

| Operation | Operator | Cycle Time | Percent Increase |
|-----------|----------|------------|------------------|
| | | x | y |
| 1 | 1 | 30.893 | 16.531 |
| | 2 | 28.210 | 21.705 |
| | 3 | 33.051 | 21.427 |
| 2 | 1 | 30.463 | 14.549 |
| | 2 | 35.000 | 29.591 |
| 3 | 1 | 38.147 | 9.107 |
| 4 | 1 | 222.818 | 12.610 |
| 5 | 1 | 150.850 | 17.635 |

Σx 569.432
 Σx^2 78829.607
 $\Sigma x \Sigma y$ 81325.709

Σy 143.155
 Σy^2 2843.741
 Σxy 9127.445

Line of Least Squares.

$$a = \text{slope} = \frac{N \Sigma xy - \Sigma x \Sigma y}{N \Sigma x^2 - (\Sigma x)^2} = -.027$$

$$b = y \text{ intercept} = \frac{\Sigma x^2 \Sigma y - \Sigma x \Sigma xy}{N \Sigma x^2 - (\Sigma x)^2} = 15.972$$

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OPERATION OF COMMISSION COMPANIES
 BETWEEN 1900 AND 1905
 AND PRESENT INCREASE IN COSTS FOR AVERAGE OPERATION

Operation Company Yearly Time Average Increase

| 1 | 2 | 3 | 4 |
|----|----|--------|--------|
| 1 | 1 | 20.000 | 10.000 |
| 2 | 2 | 20.000 | 10.000 |
| 3 | 3 | 20.000 | 10.000 |
| 4 | 4 | 20.000 | 10.000 |
| 5 | 5 | 20.000 | 10.000 |
| 6 | 6 | 20.000 | 10.000 |
| 7 | 7 | 20.000 | 10.000 |
| 8 | 8 | 20.000 | 10.000 |
| 9 | 9 | 20.000 | 10.000 |
| 10 | 10 | 20.000 | 10.000 |

$\sum x = 55$
 $\sum y = 110$
 $\sum xy = 110$
 $\sum x^2 = 385$
 $\sum y^2 = 110$

Line of best fit

$$a = \text{slope} = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sum x^2 - \frac{(\sum x)^2}{n}} = 1.00$$

$$b = \text{intercept} = \frac{\sum y - \frac{\sum x \sum y}{n}}{n} = 1.00$$

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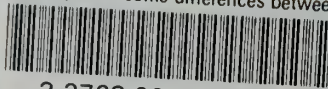
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